§30. Kinetic Model of Magnetic Field Reconnection

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A kinetic model of non-steady magnetic field reconnection is proposed to examine an effective acceleration of particles to very high energy. We consider the model of the two colliding plasmas as shown in Fig.1. The magnetic field is assumed to be given by

$$B_{zi} = (B_0/2)[\tanh \eta_i + (-1)^i], \qquad (1)$$

$$\eta_i \equiv ky + kv_i t + h_i(kz) + \phi_i, \qquad (2)$$

where the value ϕ_i is the phase constant and $2\pi/k$ means a front width of the plasma. The subscripts i =1,2 stand for the right-hand side plasma and the left-hand side one. The two magnetized plasmas approache each other from both sides along the y-axis with the phase velocity v_i. We assume that a geometry of the magnetic field is given by a function $h(\zeta) = \alpha\zeta^2$.

In order to obtain another electromagnetic field components, we first use the equations $\nabla \cdot \mathbf{B} = 0$ and (1). Then, the component B_y is given in the form

$$B_{yi} = -(\mathrm{d}h_i/\mathrm{d}\zeta)B_{zi}, \qquad (3)$$

and the electric field E_x is explicitly derived from the relation $\nabla \times \mathbf{E} = -(1/c)(\partial \mathbf{B}/\partial t)$:

$$E_{xi} = (\partial \eta_i/\partial t)B_{zi}, \qquad (4)$$

where $\zeta = kz$. To satisfy the sufficient condition $\mathbf{E}\cdot\mathbf{B} = 0$ of the frozen-in state, the uniform components of the electromagnetic fields are ignored, i.e., $B_x = 0, E_y = E_z = 0$. The flux transport velocity of the magnetic field is given by $\mathbf{v}_E = c\mathbf{E} \times \mathbf{B}/B^2$. Thus, the plasmas travel together with the magnetic fields.

Since each plasma has the anti-parallel component of the magnetic field B_z, the magnetic-null region or the magnetic neutral sheet is generated by the colliding of the plasmas. The field geomerty is given by adding the two plasma fields as follows: $(B_z^t, B_y^t, E_x^t) \equiv (B_{z1}+B_{z2}, B_{y1}+B_{y2}, E_{x1}+E_{x2})$. For simplicity, we consider a symmetric configuration with respect to xz plane, i,e., $v_2 = -v_1 = v_p, h_1 = -h_2 = h$ and $\phi_1 = -\phi_2 = \phi$. Therefore, a concrete style of the fields can be written in the form

$$B_z^t = \frac{B_0}{2}(\tanh \eta_1 + \tanh \eta_2), \qquad (5)$$

$$B_y^t = -\frac{B_0}{2}\frac{dh}{d\zeta}(\tanh \eta_1 - \tanh \eta_2 - 2), \qquad (6)$$

$$E_x^t = \frac{\beta_p B_0}{2}(-\tanh \eta_1 + \tanh \eta_2 + 2), \qquad (7)$$

where $\beta_p = v_p/c$ is the velocity normalized by the light speed c. The field configuration presented here is similar to that of the two-dimensional time-independent electromagnetic model which is proposed as a steady-state reconnection model[1].

By using these fields, we can neumerically solve the equation of motion in the relativistic regine. The model will be usefull to investigate a mechanism of high-energy particle generation near the magnetic neutral sheet from microscopic pints of view.

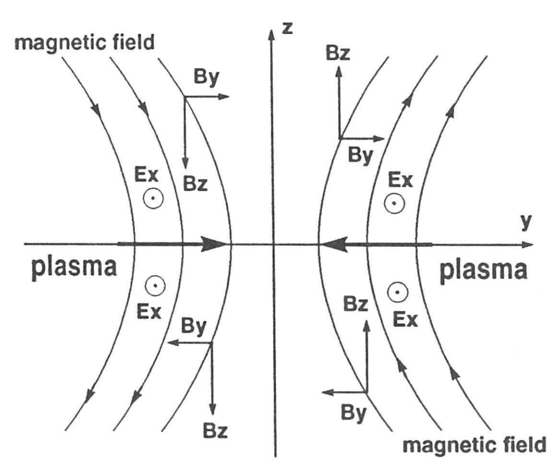

Figure 1: A kinetic model of the magnetic field reconnection

References

[1] B.U.Ö.Sonnerup, *Solar System Plasma Physics Vol. III, ed. L.T.Lanzerotti, C.F.Kennel and E.N.Parker*, North-Holland Pub. Comp. (1979) pp.46-108.